SOLAR SYSTEM STUDIES WITH THE IUE: 1982 - 1984

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ABSTRACT

Planetary observations with the IUE in the last two years are summarized. These include work on the atmospheres of comets and the giant planets; aurorae; rings and circumplanetary environment. Planetary requirements for future Earth-orbital astronomical observatories are also described.

INTRODUCTION

This review includes published papers in the area of planetary science since the previous IUE symposium (NASA CP 2238), as well as several works in progress. It is incremental, not cumulative. It does not represent an exhaustive literature search, but rather a sampling of the most important recent work. Additional references may be found in the papers cited.

Topics summarized below include comet IRAS - Araki - Alcock; the composition of the upper atmospheres of Saturn, Jupiter and Uranus; Saturn's rings; aurorae on Jupiter and Uranus; emissions from the low latitude, upper atmospheric region of Jupiter; and the torus which surrounds Jupiter and includes the orbit of the innermost Galilean satellite, Io.

Finally, those requirements on future space observatories that are unique to planetary studies are described briefly.

COMETS

Comet IRAS - Araki - Alcock (1983d) was the closest Earth-approaching comet of this century, coming within 0.032 AU and permitting the highest spatial resolution of any recent comet. Despite the relatively short notice of the comet's imminent arrival, the IUE observatory was sufficiently flexible to schedule it as a target of opportunity, including the period of closest approach.

This flexibility was magnificently rewarded when A'Hearn, Feldman and Schleicher (1983) discovered emissions from the S_2 molecule near the cometary nucleus. They found more than 10 bands of the B - X system between 2800 and 3100 A. This was the first observation of that molecule in any astronomical object. The discovery was a direct consequence of the very high spatial resolution. In other, more distant comets, the S_2 emitting region would be too small to be observed by the IUE. The derived emission scale length was only 450 km, implying that the S_2 originated in the nucleus itself. Other species observed in this comet, CS and OH, are thought to be dissociation products of coma molecules (CS_2 and H_2O, respectively) and have much larger scale lengths, typically 10^5 km.

The most important question regarding this molecule is whether it is primordial or recently formed. A'Hearn et al. suggest that it may be the result of cosmic ray irradiation, which can penetrate the comet's nucleus and form S_2 from other sulfur-bearing molecules. They propose a test of their hypothesis: short period comets should have much less S_2 than long period ones, because the latter have sufficient time to accumulate the chemical by-products of the cosmic ray energy deposited within their volatile bulk, before these by-products are released to space during the active perihelion phase.

ATMOSPHERIC COMPOSITION OF SATURN, JUPITER AND URANUS

Winkelstein et al. (1983) have modelled the reflectivity of Saturn from 1500 to 3000 A. They agree with the abundances and vertical distributions of C_2H_2 and C_2H_6 derived from Voyager infrared observations, but not with the PH_3 vertical distribution (Courtin et al., 1981). They further require an additional absorber, and suggest that H_2O provides the best fit. If so, this almost certainly requires an external source of oxygen for Saturn's upper atmosphere. Any internal H_2O should be frozen out at levels much too low to be seen in the ultraviolet, where Rayleigh scattering limits photon penetration to the upper few millibars. Saturn's rings are one potential source of oxygen, through trapped particle spattering of H_2O ice.

Wagener (unpublished) has almost completed a similar study for Jupiter. He finds that C_2H_2, C_2H_6, and NH_3 are required, and that trace amounts of other gases including PH_3, H_2O and C_3H_4 (allene) are consistent with the spectrum, although unique identification of these latter species is much more difficult.

Caldwell et al. (1984) have reviewed ultraviolet observations of Uranus and Neptune. Present data are compatible, within calibration uncertainties, with either a clear upper atmosphere on both planets or a thin haze on both. It is probable that whatever the degree of haziness is, it is very similar on both planets. Since infrared observations show clearly that ambient conditions are much different between the upper atmospheres of these two planets, Occam's razor suggests that both are clear.

Caldwell et al. (1984) further claim an apparent secular brightening of Uranus between 1980 and 1982, which is quantitatively consistent with a decrease in C_2H_2 abundance from a mixing ratio of $\sim 3 \times 10^{-8}$ to near zero over that period. However, there is no compelling spectroscopic identification of C_2H_2, because the abundance is certainly small and because the signal to noise ratio is only moderate.

SATURN'S RINGS

Caldwell and Wagener (unpublished) have merged a large number of SWP and LWR spectra to demonstrate that Saturn's rings have a rather flat, low reflectivity (~ 0.02) from 3000 A to 1700 A. The large number of spectra, with a wide range of exposure times, was necessary because of the limited dynamic range of the IUE and the strong decrease in absolute signal level below 3000 A for all objects shining by reflected sunlight.

There is a suggestion of a decrease in reflectivity at 1700 A, which would be expected for H_2O ice and which could contain information on the ring particle size distribution. 1700 A does not represent the absolute limit of IUE sensitivity, because the longest SWP exposure in the series was only 75 minutes. However, the falling Solar flux at shorter wavelengths precludes extension of IUE results much farther.

Holberg (unpublished) has stated that ring reflectivity data from the Voyager UVS instrument show that the reflectivity is also low and flat in the range of that instrument's sensitivity, 600 - 1700 A. This nicely complements the available IUE data, and calls into question the suggestion that the reflectivity may be decreasing right at 1700 A.

Clearly there is potential for learning about the physical characteristics of Saturn's ring particles from such data. Further IUE observations to establish an area of spectral overlap with Voyager would be most useful, and are well within the IUE capability.

AURORAE ON JUPITER AND URANUS

The existence of auroral phenomena on Jupiter has been known for many years. Current research activity in this area consists of monitoring various aspects of the emission in great detail. Skinner et al. (1984) have summarized their latest observations of H I Ly α (1216 A) and H_2 Lyman - and Werner-bands (1600 A). They find that the northern emission is confined within longitudes 120° and 240°, which includes the northern magnetic pole. They cannot differentiate between the magnetotail auroral zone and the Io torus auroral zone as the most probable location of the emission. It is of some interest that other investigators find excess infrared emission from a similar region on Jupiter (Caldwell, Tokunaga and Orton, 1983).

An aurora on Uranus has recently been discovered independently by two investigations with the IUE (Durrance and Moos, 1982; Clarke, 1982). In each case, strong Ly α emission is detected in excess of the geocoronal and interplanetary background. The most plausible explanation is collisional excitation of hydrogen by magnetospheric particles. For example, Rayleigh scattering of Solar Ly α radiation by H_2 in Uranus can be ruled out by the absence of the Raman shifted line at 1280 A. Strong variability is associated with the Uranian aurora.

The cosmogonic significance of this discovery is that Uranus must have a magnetic field. It is now well known that Jupiter and Saturn have such fields. However, the bulk density of Uranus requires that its internal composition be significantly different from those of Jupiter and Saturn, so that it had formerly been possible to speculate that Uranus would not have a magnetic field.

UPPER ATMOSPHERIC EMISSION FROM JUPITER

Skinner et al. (1983) have monitored the brightness of Jovian Ly α emission from late 1978 to early 1982. The primary excitation mechanism is resonance scattering of solar Ly α by H I. They find enhanced emission at the

center of the disk near System III longitude 100° over the entire observation period. The observations indicate no substantial changes in Jovian H I concentration over the period, and disagree quantitatively with Voyager UVS observations.

IO TORUS

Moos et al. (1983) have obtained a high quality SWP spectrum of the Io torus, showing emission lines of S II, S III, S IV and O III. The lines include a pair at 1713.8 and 1729.2 A which have been identified as $^5S_2 - {}^3P_{2,1}$ intercombination doublet of S III. This identification was made before it was observed in the laboratory, but since has been confirmed by P. L. Smith (private communication). This transition, and the one at 1199 A, may be very useful in determining electron temperatures over a wide range in astrophysical plasmas.

FUTURE MISSIONS

As the observing schedule for the IUE moves into its seventh cycle, it is prudent to look ahead to future missions, and to pass on previous experience to those who will build the new spacecraft. Since it is infintely easier to incorporate features into a satellite during its design rather than later, and since planetary observations have their own special requirements, this review will end with a brief summary of what is desirable.

The primary need for planetary work is to be able to track moving targets. However, there is a secondary requirement that is easy to overlook. Because planets are relatively close, they have significant parallax effects. For the case of Mars at opposition, this is at least 40 arc seconds per orbit. It is therefore extremely inefficient to guide on stars for planetary work. The ability to track on the center of light of a bright, extended object like Mars, Jupiter or Saturn would be extremely useful. (Space Telescope will not have this capability, unfortunately, although OAO-A2 did in 1968!) Alternately, the ability to guide on a bright satellite and to offset to specific planetary locations would be appreciated. The offset range should be at least of order tens of arc minutes, to permit observations of whole planetary systems, including magnetospheres, tori and faint satellites. The system should be smart enough to remember that the satellites are moving with respect to the planets, at a known rate.

Venus has always been a problem because previous spacecraft designs have not included the capability to point easily within 45° of the Sun. Certainly it becomes increasingly difficult to approach the Sun, but there is no apparent physical discontinuity at 45°; 40° would be much preferable.

The maximum required tracking rate cannot be specified absolutely. The limiting class of object here is the comets. Since these are probably too diffuse for self-guiding, a different technique will be required, presumably tracking on gyros with appropriate selectable drift rates. It is noted that the maximum apparent rate for comet Halley in 1986 will be 0.2 arc seconds per record of time.

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ADDENDUM Since this manuscript was written, a preprint by P. S. Butterworth and A. J. Meadows, entitled "Ultraviolet reflectance properties of asteroids" has been received (Icarus, in press, 1984). It describes IUE LWR spectra of 28 asteroids. Absorption features in different classes of asteroids are presented, and compared to available laboratory data. It is suspected that the observed features are due to titanium and iron ions in silicate assemblages. This paper also presents a very readable discussion of the difficulties associated with observing planets by the IUE.